Tandem Operation in the Bell System

By F. M. BRONSON

Tandem operation is becoming of increasing importance in the Bell System. The operating and service features of the different types, and the conditions under which each type is used, are outlined. Charts are included showing, schematically, typical trunking arrangements in the various systems. The increasing use of tandem operation on traffic handled at toll boards is discussed.

THERE are 14,000,000 telephones in the Bell System, served from 6,800 central offices. Means must be provided to permit any one of these telephones to be connected to any of the others. Therefore, facilities must be provided for interconnecting all of the 6,800 central offices. Obviously it would be impracticable to provide direct circuits from each central office to all of the others; this would require $[N \times (N - 1)/2]$, or more than 23 million, groups of two-way circuits, most of which would carry little or no traffic. To keep the number of circuit groups within reasonable limits and to obtain reasonable circuit efficiency, direct circuits are provided only between offices having a sufficient community of interest to justify them. Connections between the others are obtained, as required, through switching operations performed at one or more intermediate points.

The 14,000,000 telephones referred to originate 75,000,000 daily calls, the great bulk of which, of course, are local calls dialed direct by customers or handled at local manual switchboards. There are, however, about 1,500,000 short haul station-to-station toll calls which, because of the close community of interest between the cities involved, are also handled by local operators by methods essentially similar to those used on local calls. Obviously, these are largely concentrated in sections of the country having greatest population densities, such as in the New York City, Boston, and San Francisco metropolitan areas.

To facilitate the interconnection of central offices in areas having large volumes of local and short haul toll traffic, switching arrangements designed particularly for this purpose are frequently provided. These are known as tandem arrangements and, for the purpose of this paper, may be more specifically defined as facilities for the intermediate switching of traffic between central offices other than those facilities involving the use of outward, inward and through toll switchboards and of local switchboards which interconnect trunks of the

ringdown signaling type. More recently, tandem arrangements have been employed in toll offices in connection with the toll lines used for long distance calls, all of which, with a few exceptions, are handled over ringdown signaling circuits.

It is the purpose of this article to describe the operating and service features of the different types of tandem arrangements employed in the Bell System and to indicate the extent to which they are used. Tandem equipment having trunks incoming from other tandem equipment, is a subtandem; some equipments operate both as tandems and subtandems.

A consideration of tandem operation may logically begin with the switching requirements of a single local exchange area. It follows from our definition that a tandem connection involves the cooperation of at least three different offices for its completion. So long as all switching operations are confined within a single office there is, therefore, no occasion for tandem connections. Neither is there any occasion for them when the number and relative locations of the various offices, call them A, B, and C, etc., within the exchange area are such that it is still practicable to handle interoffice calls over direct trunks. With increase in area and number of offices, a point is obviously reached, however, where it is no longer practicable to go, for example, from office A to office U directly, U being located in a remote division of the exchange, although it will still be feasible to go directly between offices A, B, and C, and between offices U, V, and W. Given such an extended exchange area, it will be found to contain some intermediate geographical position at which a tandem office can be profitably located with trunks extending to all the local offices and with switching facilities such that calls from A, B, and C to U, V, and W will be routed to it and will be completed by the interconnection of trunks between the tandem office and these various outlying offices. Such a tandem office would of course be a local tandem office.

Passing from the problem presented by the handling of local traffic within an exchange area, and reserving discussion for later paragraphs, it may be stated as evident that numerous other situations arise within the telephone plant for one or another type of tandem operation. These it is convenient to classify as follows:

I. Manual tandems, at which connections are made manually by plug and jack operation. These include—
   a) Manual straightforward tandems, for completing connections from manual trunks to manual trunks.
   b) Call indicator tandems, for completing connections from dial trunks to manual trunks.

c) Toll office tandems, for completing connections from manual trunks to ringdown toll circuits.
d) Straightforward toll line tandems, for completing connections from straightforward toll circuits to toll switching trunks.
e) Toll switching trunk tandems, for completing connections from manual trunks to manual toll switching trunks.

II. Dial tandems, at which the connections are made wholly by means of switch mechanisms controlled either at the tandem office or at a distant office. These include—

a) Operator tandems for completing connections from manual trunks to dial (or manual) trunks.
b) Full selector tandems, for completing connections from dial trunks to dial (or manual) trunks.
c) Trunk concentrating tandems, for automatically concentrating or collecting traffic which is to be completed over either manual or dial trunks.

Manual trunks include all types of trunks over which the order is passed orally by an operator or by a machine as in the case of call announcer trunks. Dial trunks include those over which the order is transmitted in the form of electrical impulses.

Traffic normally routed over direct straightforward trunks frequently is handled through a tandem system during the night and other hours of light traffic. This is sometimes an economical arrangement since it makes it unnecessary to provide incoming "B" operators during such hours except on positions handling the tandem completing trunks. The speed of connection at such times is substantially as fast as over direct trunks because of the number of "B" positions which it would be necessary otherwise to cover with a small number of operators. Also, a tandem system may be used as an emergency routing during periods when direct trunk groups are out of service because of cable or other failure. Frequently tandem systems are used as overflow routings for traffic normally handled over small direct trunk groups.

Table I indicates the number of the different types of tandem systems in use in the Bell System. In addition to systems of the types shown, tandem operation is obtained through the use of regular local central office equipment in a number of cities where the volume of eligible traffic is very small.

Manual Tandems

Manual Straightforward Tandems

In these tandem systems the incoming and outgoing trunks are of the straightforward type. The incoming trunks are terminated on

TABLE I

TANDEM SYSTEMS AT BELL SYSTEM TOLL CENTERS
(These Constitute Most of the Tandem Systems in Use)

Type of Tandem	No. in Use
Manual Straightforward Tandems	13
Call Indicator Tandems	5
Toll Office Tandems	27
Straightforward Toll Line Tandems	3
Toll Switching Trunk Tandems	2
Panel Sender Tandems—Total	6
—With Operators' Positions	5
Panel Office Selector Tandems	34
Step-By-Step Tandems—Total	61*
—With "B" Board Operators' Positions	5
—With Intermediate Dialing or Key Pulsing Operation	4
Trunk Concentrating Tandems—No. of Cities	9†

* 26 of these have trunks incoming from other tandems.
† With 148 groups of trunk concentrating switches.

single-ended cords on the tandem positions, and, in all but the smallest boards, the trunks are connected automatically to the tandem operator in rotating sequence, a flashing supervisory lamp associated with the trunk indicating to the tandem operator the trunk to which she is connected. When the tandem operator is in this fashion connected to a trunk which an originating operator has selected and over which she wishes to have a call completed, both operators receive momentary tone signals indicating this fact and the originating operator passes the name of the central office desired. The tandem completing trunks appear in the outgoing trunk multiple at the tandem board, usually with idle trunk indicating lamps, and the tandem operator extends the connection from her position by simply plugging the incoming trunk into an idle trunk to the office desired. Plugging into the trunk automatically signals the "B" operator at the called office. The tandem operator's telephone set may be released from the incoming trunk, either by means of a release key provided at her position for that purpose or by the act of plugging into the outgoing trunk. The release key enables the tandem operator to receive a call while establishing the connection on a previous call.

In order to distribute the load and assure the minimum of delay at the tandem board, the various groups of incoming trunks are subgrouped and the subgroups terminated on different tandem positions. In addition, on the larger trunk groups, arrangements are provided so that if the operator upon whose position a subgroup is located is busy, when one or more operators upon whose positions other subgroups terminate are idle, this is indicated to the originating operator in order that she may select a trunk to an idle tandem operator. The number

of trunks handled by the various tandem operators can be varied from hour to hour by means of keys located between each group of 10 cords.

Release of the tandem trunk by the originating operator gives a disconnect signal, simultaneously at both the tandem and "B" boards, and the tandem and "B" operators then take down the connection. The tandem trunk may be reselected for a new call even before the tandem operator has taken down the cord on the previous call.

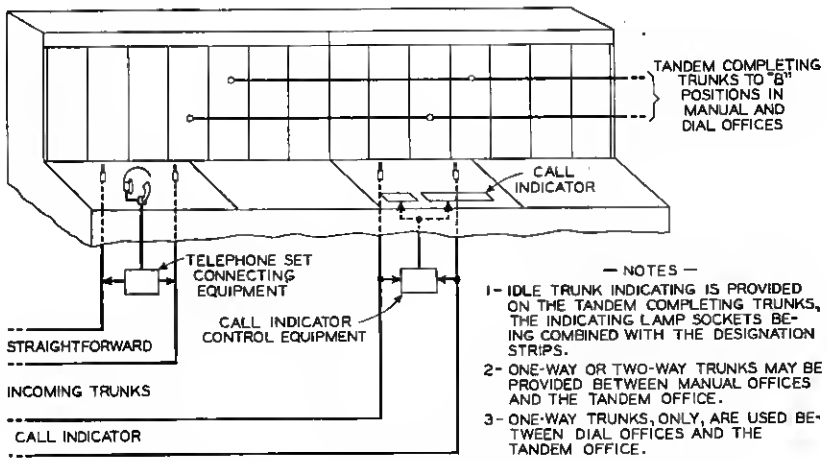

Fig. 1—Manual automatic listening straightforward and call indicator tandem arrangements.

Figure 1 shows, schematically, the circuit and equipment arrangements in the manual straightforward tandem system. Figure 2 is a photograph of the manual straightforward tandem switchboard which serves Detroit, Michigan, and surrounding communities, while Fig. 3 indicates the scope of the Detroit Tandem System.

Where the volume of traffic to be switched is too small to warrant a tandem switchboard, tandem operation frequently is obtained by routing the traffic over straightforward trunks terminating on manual "B" positions at a convenient local office and providing trunks from these positions to other central offices. The operators at these manual "B" positions, therefore, combine the functions of tandem and "B" operators.

Call Indicator Tandems

When manual offices are converted to dial, it is necessary to provide means for completing calls from dial subscribers to all offices, including manual offices, within their local dialing area. The usual arrangement

with respect to manual offices to which direct trunks can be justified, is to display the number dialed by the customer on a call indicator located on a "B" position in the manual office, the operator at this position completing the connection to the called subscriber's line. Where direct trunks cannot be justified, the call indicator may be located on a manual straightforward tandem position, thus forming a "call indicator tandem." The operation at the tandem board is dissimilar in the

Fig. 2—Detroit manual straightforward tandem switchboard.

following respects to the manual straightforward tandem operation described above: *a*) the display of the central office code and digits of the called number, as dialed by the subscriber, take the place of the name of the central office desired passed orally by an operator; *b*) the tandem operator passes the order orally to the called office; *c*) the tandem operator is not connected automatically to the incoming trunk but, upon receiving a signal on a trunk indicating an incoming call, depresses a display key which connects her telephone circuit to the trunk and causes the number which has been dialed to be displayed on the call indicator.

The call indicator tandem arrangement is shown schematically in Fig. 1, and a photograph of a typical call indicator tandem position is shown in Fig. 4.

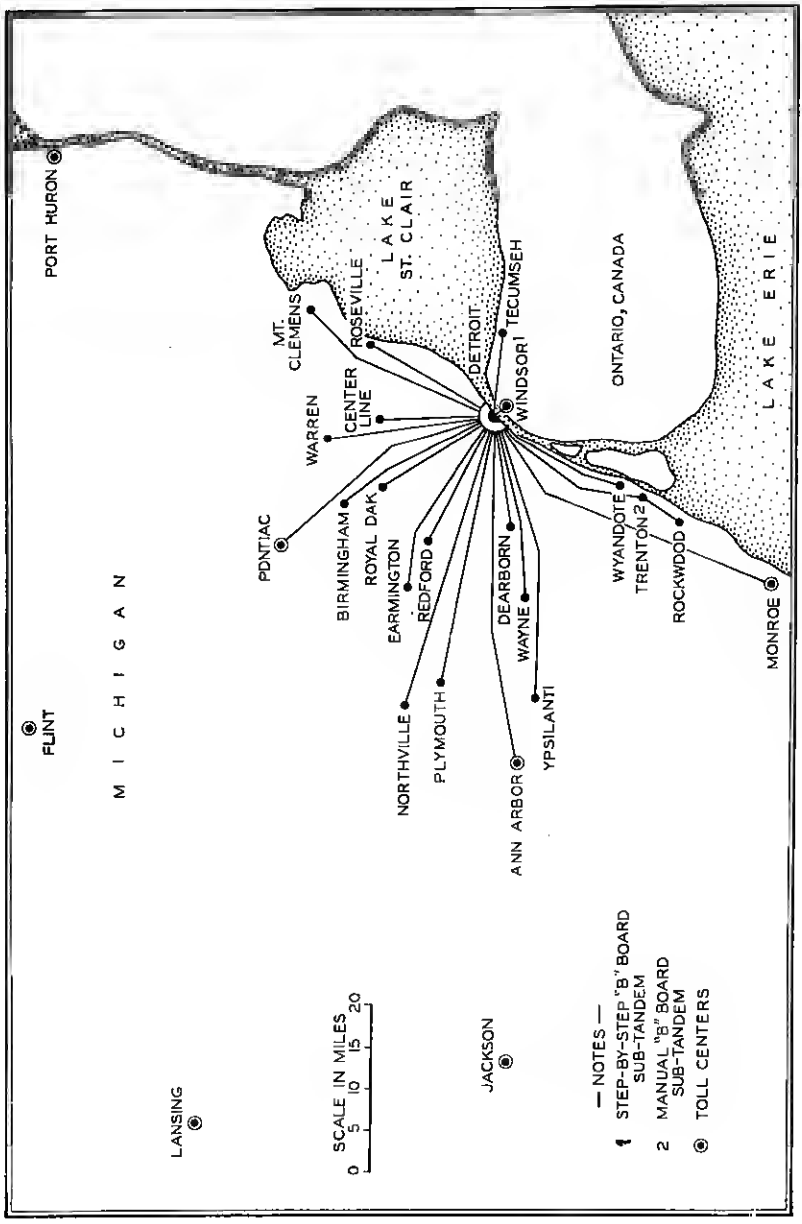

Fig. 3—Detroit tandem area.

Fig. 4—Call indicator tandem position.

Toll Office Tandems

With the introduction of the combined line and recording method of toll board operation, it was necessary to provide means for giving each outward toll operator access to all of the toll circuits (instead of circuits to certain points only, as required by the former single ticket toll operating method) and in large toll offices where the transmission and switchboard multiple limitations prevent multipling all of the toll lines at the outward positions, toll office tandems provide such a means. Toll office tandems also are used as a means for making toll board circuits available to local operators, at both manual and dial

system "A" boards in multi-operating center cities,[1] to permit the "A" board handling of station-to-station toll calls over such circuits.

Except that they are arranged for establishing connections to ringdown toll lines only and have certain additional features required thereby, the operating and service features of these toll office tandems are similar to those of the manual straightforward tandem previously described. The trunks from the toll board to the tandem positions are usually of the idle-position indicating, idle-trunk indicating, type. Trunks from "A" boards have the idle-trunk indicating feature only.

The ringdown toll lines are multipled in the tandem positions and are equipped with idle-indicating lamps. When a tandem trunk is connected to a toll line, a ring of two seconds' duration is sent automatically, but a ring-release key is provided on each tandem position to permit connection to be made to a toll line without ringing, as is necessary under certain operating conditions. Subsequent rings on the toll line may be made by the originating operator.

When ringdown toll lines appear directly in the multiple before the originating operator and she finds all of the circuits in a particular group momentarily busy, she ascertains when a circuit in the group becomes idle by observing the busy signals associated with the toll line jacks. When connections to the circuits are obtained through toll office tandem equipment, the equivalent of this arrangement for ascertaining when a circuit becomes available may be obtained by providing overflow circuits connected to jacks associated with the different circuit groups in the toll line multiple at the tandem positions. The tandem operator connects the incoming tandem trunk to the overflow circuit and the first toll line in the group to become idle causes a signal indicating this to be given over the trunk to the originating operator. Should the overflow circuit also be busy, the tandem operator connects the incoming trunk to one of a common group of circuits arranged to transmit a signal indicating this condition.

Figure 5 is a photograph of one of the two toll office tandem switchboards in the Long Lines Office in New York City.

In cities not requiring the use of tandem equipment in order to give toll board operators access to the toll lines, a somewhat different toll tandem arrangement is provided for giving "A" operators access to the toll board circuits. Under these conditions the tandem operators' positions are located in line with the toll positions, and the incoming trunks may or may not have the automatic listening feature described in connection with manual straightforward tandems. If not, the

[1] A multi-operating center city is one sufficiently large to require the local operating to be distributed between two or more buildings.

tandem operator connects herself to the trunk and gives the order tone to the originating operator by operating a key associated with the trunk. The ring-release and overflow features are not provided.

Fig. 5—Toll office tandem, No. 1—Long Lines office, New York City.

In a few cases where the volume of traffic to be handled by "A" operators over toll board circuits is very small, a form of toll office tandem operation is obtained, without the use of tandem positions of the types described above, by terminating automatic signaling trunks from the "A" boards on jacks and lamps at the outward toll board positions and having the connections between the trunks and the toll circuits made by means of the regular pairs of cords. The answering jacks are multipled at a number of the toll positions and none of the features normally associated with toll office tandem equipment are provided. The toll board operator answers on the trunk verbally and after receiving from the "A" operator the name of the place desired, establishes a connection to the toll line and rings the distant office. From this point on, the "A" operator handles the call in essentially the same manner as when regular toll tandem equipment is used.

Straightforward Toll Line Tandems

While ringdown operation is the general rule at toll boards, there are a few toll board circuit groups which are operated on a straightforward basis, notably the terminal circuits between New York and Philadel-

phia. These straightforward toll lines are arranged for one-way operation and terminate on single-ended cords at automatic-listening tandem positions in the Long Lines offices in New York and Philadelphia. Regular toll switching trunks are multipled at the tandem positions for reaching the various local offices on incoming calls; idle trunks are found by the tandem operators by tip test, no visual busy signals being provided. The order for connection to the called station is given to the "B" operator at the local office by the originating operator. Ringing on the toll switching trunks is controlled by equipment in the toll line circuits. Switchhook supervision from both called and calling station is received by the originating operator as in local tandem systems. The disconnect signals at the tandem board are controlled by the originating operator. The trunks from the tandem board to the local offices are of the straightforward type. In the case of dial central offices, these trunks terminate on selectors, but an operator at an associated "B" position sets up on a key set the connection to the called subscriber's line.

Toll Switching Trunk Tandems

In a number of the larger toll offices, equipment limitations prevent the multipling of toll switching trunks to all of the local offices at all of the outward positions. Each operator has direct access in the multiple at her position to trunks to the offices from which she normally receives calls. Occasionally, however, it is necessary for operators to reach subscribers connected to other local offices, and to permit this a toll switching trunk tandem is provided. The trunks incoming to the tandem positions are of the cord-ended, key-listening, straightforward type. The originating operator passes to the tandem operator the name of the local office desired.

Dial Tandems

Dial tandems receive calls from operators and, in panel areas, from subscribers also, and are of several types.

Where there is a considerable concentration of short-haul toll traffic within an area served by two or more dial tandem systems which individually serve limited areas, it is sometimes desirable to interconnect such systems and to route calls through one or more of these tandem centers, as required. An example of this is shown in Fig. 9.

Panel Tandems

Panel tandem systems employ panel selectors and are of two general types; one known as the panel sender tandem, and the other as the

office selector tandem. Both are designed for use in cities employing panel type central offices, and therefore these tandems are used to serve only the larger cities and their environs.

Panel sender tandems use senders associated with the tandem equipment to control the electrical operation of the system. The completing trunks may be of the dial, call indicator, or call announcer types. The sender is a device which receives the impulses from the incoming trunk or tandem operators' positions, determines the routing for the call, and sets up the necessary electrical conditions for operating the panel type equipment in the tandem office and the associated equipment in the completing trunks.

These systems ordinarily include both operator tandem and full selector tandem equipment, the latter for traffic routed directly through the selectors from dial system "A" boards equipped with key sets. Local calls dialed directly by subscribers are also routed through full selector tandems when the volume of such calls is so small as not to warrant direct trunks between the originating and terminating offices.

While the equipment arrangements of the full selector tandem are such as to permit operators at dialing type dial system "A" boards (as distinguished from boards equipped with key sets) to dial numbers at the distant offices direct, it usually is more economical to route calls from these boards through the operator tandem positions. Manual "A" boards in panel areas usually are not equipped with either dials or key sets.

All of the trunks to a panel sender tandem office terminate on selectors, but on incoming calls, other than those from operators at switchboard positions equipped with key sets, or dialed by subscribers, the trunk automatically is connected to an idle tandem operator who sets up the called number on a key set provided with a row of keys for each letter and digit in the number. The tandem operator's position then is released automatically from the connection. On connections completed through either the operator tandem or the full selector tandem, disconnection, both at the tandem office and at the called office, is under control of the originating operator, or calling subscriber on calls dialed direct.

The use of call announcer trunks, which at present are designed for panel tandem systems only, permits tandem connections to be completed by key set or dialing operation to small outlying manual offices where, for equipment or other reasons, call indicators are not provided. At the called office call announcer trunks are similar to straightforward trunks, but are so arranged that the connection of the "B" operator's telephone circuit to the trunk causes the call announcer

equipment at the tandem office to reproduce over the trunk by means of a talking film the digits of the number previously set up by the originating or tandem operator.

Trunks may also be provided from panel sender tandem offices to local central offices having step-by-step equipment, to manual tandems, and to dial tandems of either the panel or step-by-step type.

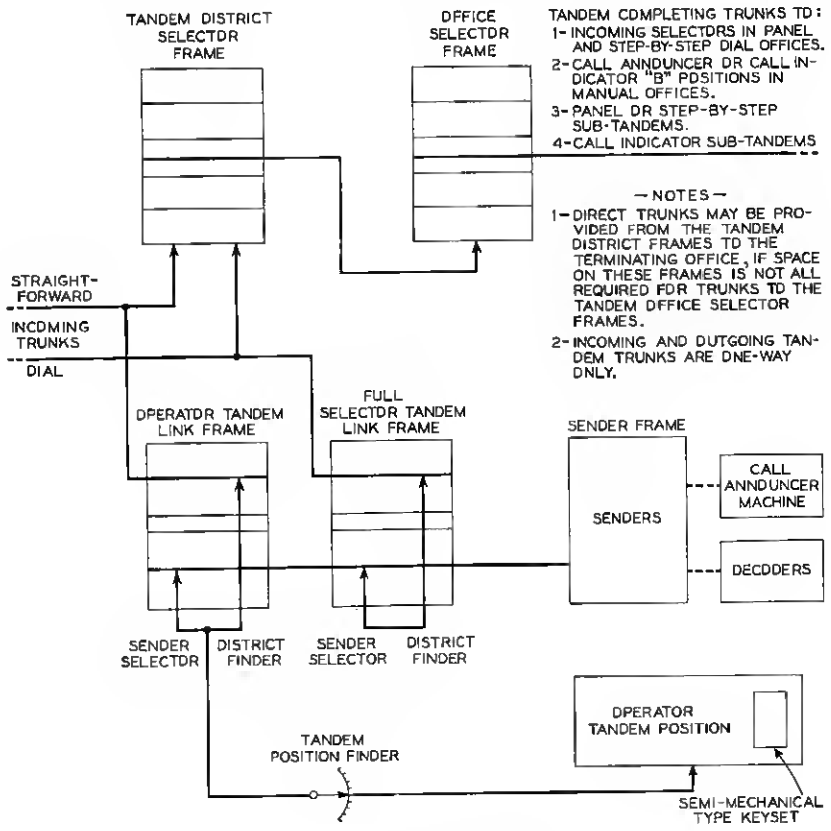

Fig. 6—Panel sender tandem system.

Figure 6 shows schematically the latest type of panel sender tandem system. Figure 7 is a photograph of the operators' positions at Suburban Tandem, one of the panel tandem systems in New York City, while Fig. 8 shows the area served by this system.

An early type of panel sender tandem system known as the semi-mechanical system is in use in New York City. It consists both of an operator tandem and a full selector tandem. The former has opera-

tors' positions equipped with key sets having a row of keys for each of the last four digits and the party line letters in subscribers' numbers, and, in addition, there are coordinate routing keys for selecting trunk groups to the various offices either inside or outside the New York City numbering plan area. In the more recent type of panel sender tandem system, trunk groups to offices outside the numbering plan area

Fig. 7—Panel sender tandem operators' positions—Suburban Tandem—New York City.

are given 3-digit codes which do not conflict with office codes within the numbering plan area, and trunk selection is made by setting up these codes on the key set. The trunks to the operators' positions of the semi-mechanical tandem are on a straightforward key-listening basis and do not have the call distributing feature.

Frequently, it is found desirable in cities served by panel central office equipment to consolidate the traffic, originating in one central office building and destined to a number of central offices in one or more distant buildings, over a single group of trunks to a distant office which serves as a distributing point. This is done by placing panel office selectors at the distant point. Such equipment constitutes an office selector tandem and is arranged to complete connections incoming and outgoing over panel dial trunks only. In all cases the connections are set up by dialing on the part of a subscriber, or by dial or key set operation on the part of an operator. The operation of the office selector tandem equipment, in establishing a connection, differs from that of the full selector sender tandem in that it is controlled by the senders

associated with the local central office equipment at the originating office, or by senders associated with the panel tandem equipment in the case of traffic first routed through the latter.

While panel sender tandem systems ordinarily include both operator tandem and full selector tandem equipment, Knickerbocker Tandem in New York City is entirely of the full selector type, being designed for traffic incoming over dial trunks only.

Step-by-Step Tandems

Step-by-step tandem systems employ step-by-step selectors, and, ordinarily, are of the full selector type without tandem operators' positions. Under these conditions, no senders are required at the tandem office and the pulses which select the central office to which connection is to be made are received over the tandem trunk. Connections may be made through a step-by-step tandem system to both dial and manual offices; to the latter by the use of straightforward, call indicator, or automatic-signaling ringdown tandem completing trunks. Call announcer trunks are not used. Release of the tandem trunk at the originating office automatically releases the tandem selectors and at the same time releases the selectors, or (except in the case of ringdown trunks) gives a disconnect signal, at the called office.

Figures 9 and 10 show, schematically, the step-by-step tandem system in Connecticut, over which most of the toll traffic within the state is handled. Similar systems are in use in Southern California,[1] and on a smaller scale, in other places.

In certain cases the increased trunk efficiency of step-by-step tandem operation is obtained, without the necessity of providing a tandem switching equipment, by locating some of the second selectors of local step-by-step central offices in a distant building serving two or more central offices to which calls are to be distributed. These "distant second selectors" combine all of the traffic to the terminating office over a single group of trunks. In other cases, increased trunk efficiency is obtained through the use of certain levels on the regular step-by-step selectors in a distant dial central office on which to terminate trunks to other central offices.

As stated, step-by-step tandems generally receive the controlling dial pulses over the incoming tandem trunks. When it is desired to complete connections through a step-by-step tandem system from manual offices, this may readily be done if the manual positions are equipped with dials. Where the volume of traffic on which dials could be used is

[1] For a detailed description of the design of the Los Angeles tandem system, see paper by F. D. Wheelock and E. Jacobsen, *Transactions A. I. E. E.*, Vol. 47.

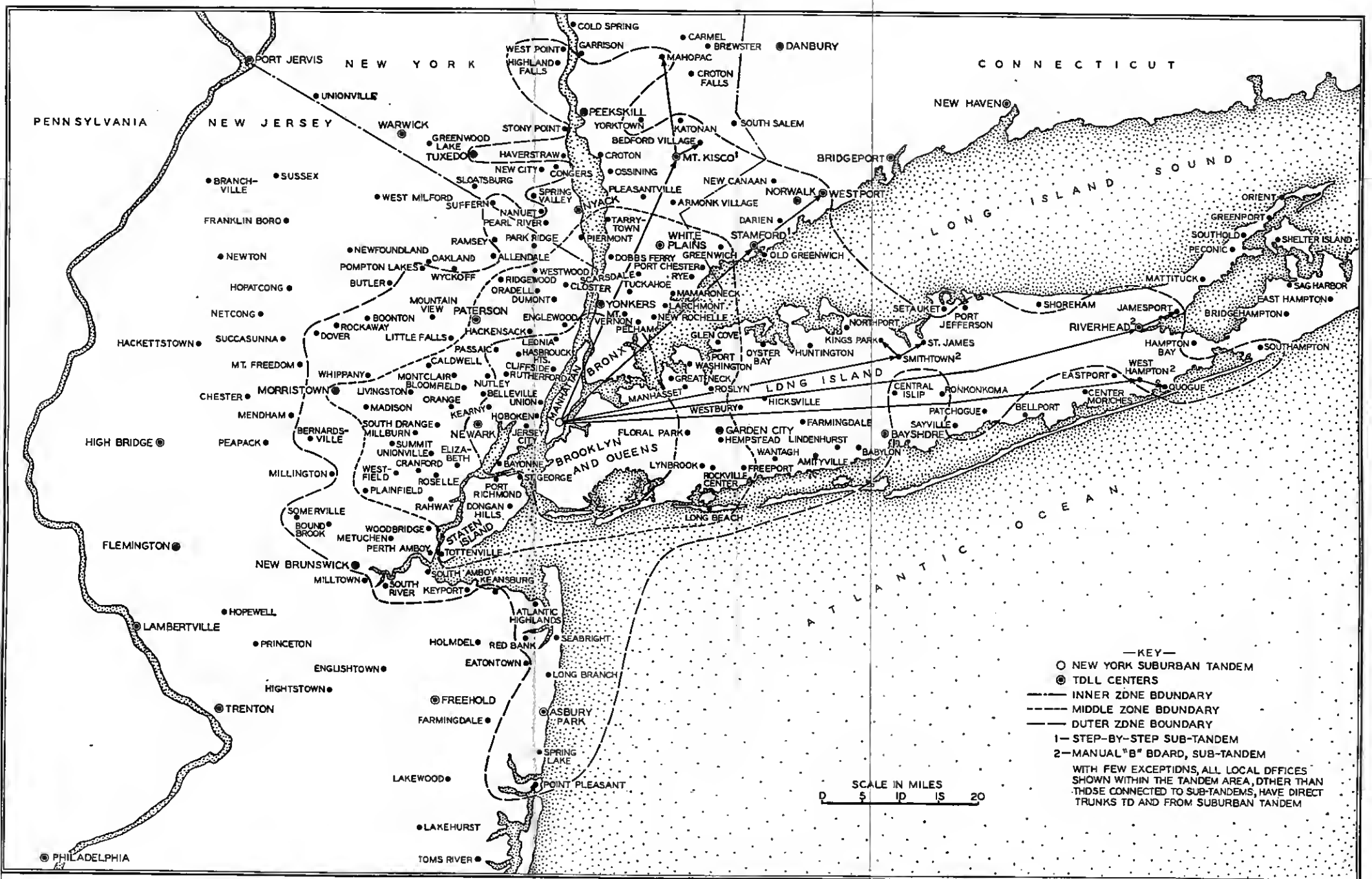

Fig. 8—New York suburban tandem area.

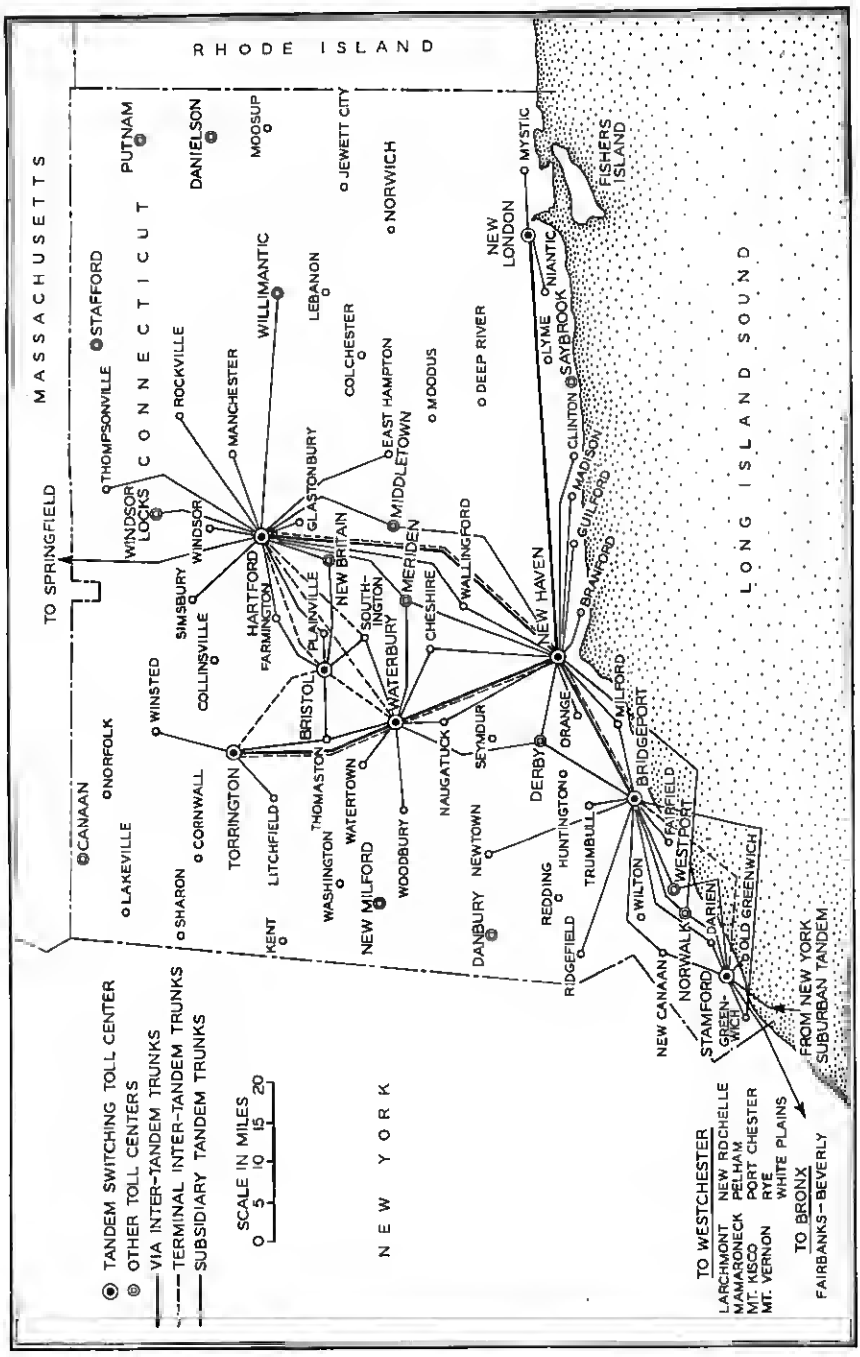

Fig. 9—Connecticut step-by-step tandem area.

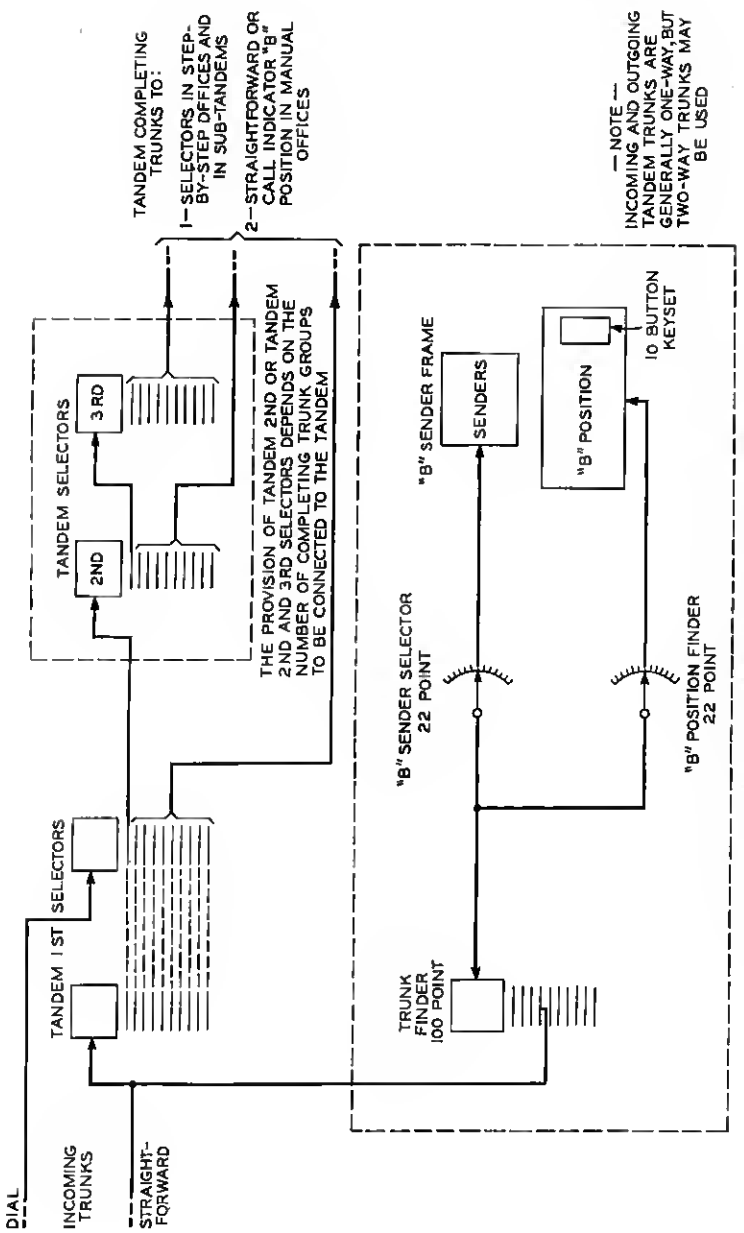

Fig. 11—Step-by-step tandem arrangement with tandem "B" position.

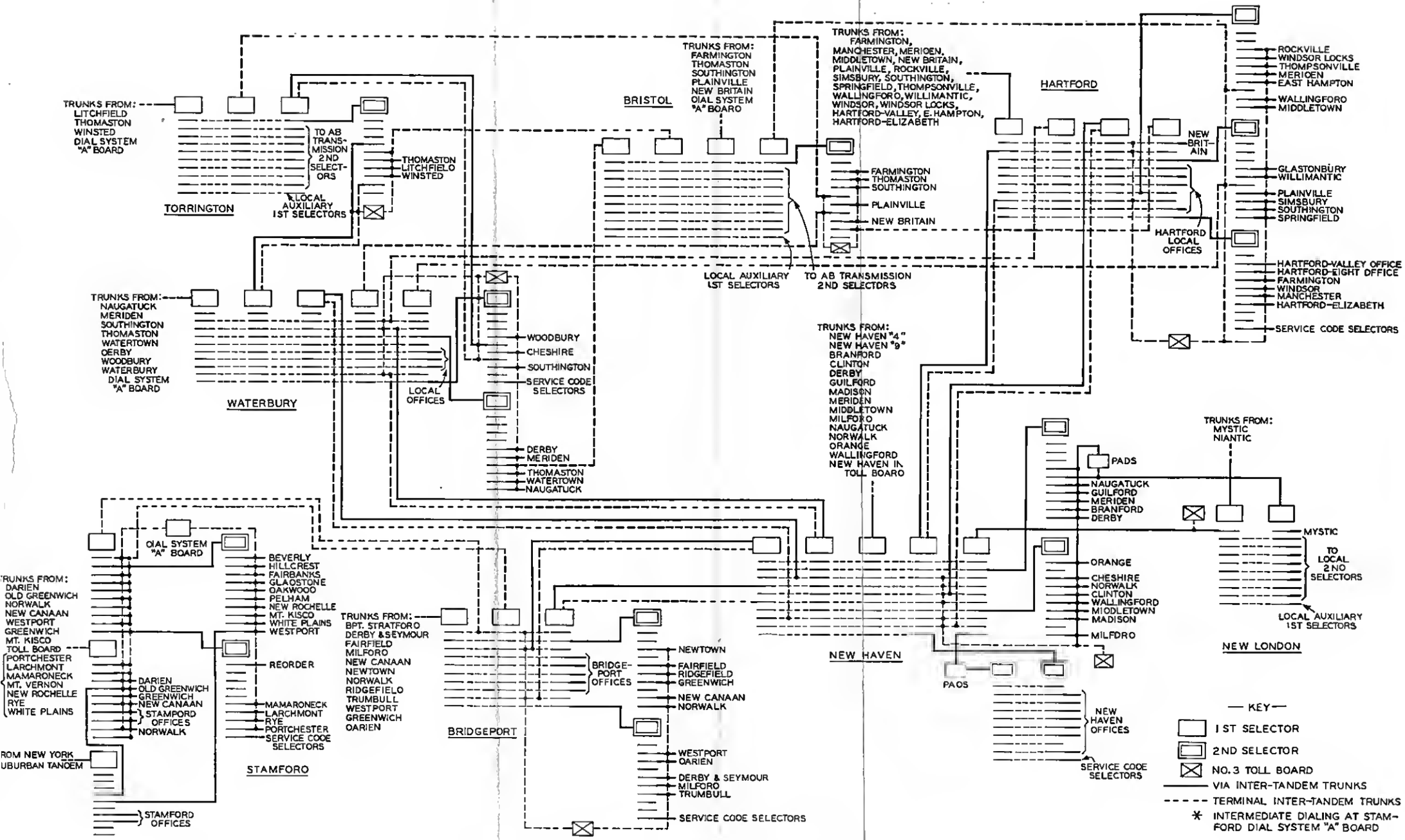

Fig. 10—Connecticut step-by-step tandem system.

relatively small, their provision may not be justified, and other means must be provided for completing connections to dial offices, whether reached over direct or tandem trunks. For tandem operation under these conditions, step-by-step "B" operators' positions, directly associated with the tandem equipment, usually are provided. The incoming trunks are of the straightforward type, and terminate on incoming selectors controlled by means of key sets on the "B" operators' positions and associated senders. An idle "B" operator is connected automatically to the incoming trunk through call distributing equipment and, upon receiving the order and setting up the required digits on her key set, her position is automatically disconnected. The final disconnection of the tandem and local office selectors is under the control of the originating operator. Except for the selectors on which the incoming trunks terminate, all of the selectors are used in common, whether controlled from the "B" positions or by pulses received over dial trunks.

The step-by-step "B" board arrangement sometimes is used as a sub-tandem in connection with manual straightforward tandem operation in a large nearby city, since it provides a convenient means for completing connections to subscribers connected to dial offices within the tandem area.

Figure 11 shows schematically the step-by-step tandem arrangement, including "B" board. Figure 12 illustrates the operators' positions.

Fig. 12—Step-by-step tandem—"B" operators' positions.

It may be mentioned, in passing, that the Connecticut tandem system shown on Fig. 10 does not make use of any step-by-step "B" board equipments.

An arrangement using intermediate dialing or intermediate key pulsing circuits is used in a few cases, in lieu of the "B" board arrangement, as a sub-tandem for completing calls incoming to step-by-step central offices from a manual straightforward tandem system in a nearby large city, such as to dial subscribers in Trenton, New Jersey, from the Newark manual tandem system. Straightforward trunks from the manual tandem switchboard terminate on step-by-step selectors, and on multipled line lamps and answering jacks in the regular switchboard at the incoming end of the trunk, with an auxiliary circuit for lighting the line lamps on an incoming call. When the inward operator plugs into an answering jack in response to a lamp signal, an order tone automatically is sent back over the trunk to the originating operator, who thereupon passes the called number. On key pulsing switchboards, the inward operator sets up on her key set, the desired number, and disconnects from the trunk. On dialing boards, the inward operator dials the called number over a dialing jack associated with the trunk, using a second cord, and disconnects both cords. Release of the connection at the tandem and called offices is under the control of the originating operator.

When used in conjunction with a step-by-step tandem, the intermediate dialing or key pulsing arrangement serves the same purpose, for a limited amount of traffic, as the step-by-step "B" board arrangement described above.

Trunk Concentrating Tandems

Where small volumes of traffic to the same terminating point originate at a number of offices which are closely associated, geographically, trunk costs frequently may be reduced through the use of trunk concentrating switches. Both direct trunks and trunks to a tandem system are treated in this manner.

While different types of switches are used under the various conditions encountered in practice, all function automatically to select a trunk in a common trunk group, or the switches are permanently associated with the common trunks and operate to find the incoming trunk on which a call is waiting. No dial pulses are required to cause the connection between the trunks to be made, and to switchboard operators the outgoing trunks are practically the equivalent of direct trunks to the called office, or to the tandem office, as the case may be.

Figure 13 shows schematically the use of trunk concentrating

switches for giving local operators in Philadelphia access to a common group of trunks terminating on the straightforward toll line tandem in New York City. A more extensive use on intercity traffic is in

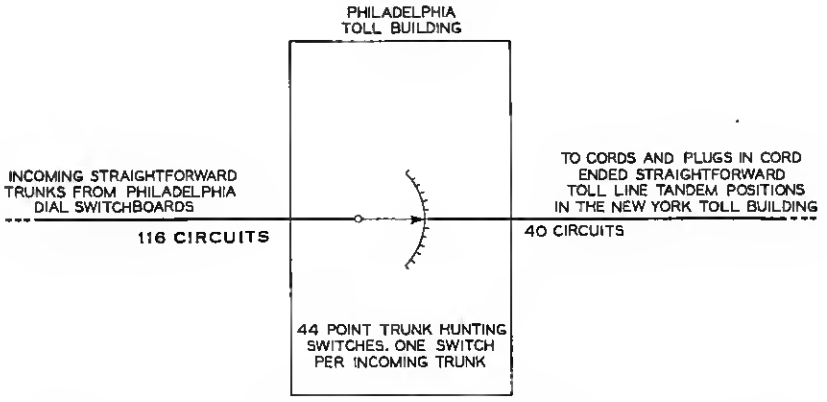

Fig. 13—Trunk hunting switch arrangement for Philadelphia to New York station-to-station "A" board toll traffic.

San Francisco and Oakland, California, chiefly for giving offices in each of these cities direct access to offices in the other city. In San Francisco, 62 incoming trunk groups containing 384 trunks are concentrated on 19 trunk groups and 239 trunks. In Oakland, 188 incoming trunk groups, containing 881 trunks, are concentrated on 25 trunk groups and 333 trunks.

Transmission Arrangements Affecting Traffic Operation

Tandem systems, unlike the general long distance system, operate within definite areas and the associated trunks usually are designed to give satisfactory transmission on connections between any two offices in the tandem area. In some of the larger systems, however, the tandem area is divided into transmission zones and the arrangements provided for traffic between the different zones may require the selection of the proper trunks or paths on the part of the operators.

One arrangement is to introduce telephone repeaters in certain of the paths between the selectors in the tandem equipment, and to route connections requiring repeater gain through these paths. Figure 14 shows schematically the Los Angeles long-haul step-by-step tandem system, in which this arrangement is used. It will be noted, for example, that connections from offices in the Metropolitan Area (Group I) to Long Beach and Santa Monica use no repeaters at the tandem office; and that connections from certain outlying offices

(Group II) are routed through one group of repeaters reached from the "O" level of the incoming 1st selectors, if destined for Long Beach and Santa Monica; and through a different group of repeaters reached from the 6th level of the incoming 1st selectors, if destined for the Norwalk-Artesia-Bellflower exchange area. The transmission gain of this second group of repeaters is higher than that of the first group.

Another arrangement is to use terminal repeaters in the tandem trunks. and to provide pads in certain of the paths between the tandem switches. The longer-haul connections are routed through the tandem switches over paths not containing pads, while terminal and other short-haul connections are routed over paths containing pads. This arrangement is indicated in connection with the New Haven tandem arrangements shown in Fig. 10, where the trunks to New London appear on the 6th level of the tandem second selectors without pads, and on the 7th level with pads.

Still another means of obtaining transmission gain is to provide a second group of trunks to the tandem office over which calls to the more distant offices are routed. For convenience to the operators, these trunks are sometimes designated as a separate tandem system as, for example, Empire Tandem in New York City, which consists of special, high-grade trunks to Suburban Tandem. In the Southern New England System, two groups of trunks are provided between certain of the tandem centers, as shown in Fig. 9, the routing code determining which group shall be used.

Speed of Operation

As might be expected, the speed with which connections can be made through tandem systems varies considerably, depending upon the type of arrangement employed. Table II indicates the relative theoretical speed of operation, in seconds, of some of the more common tandem arrangements. Direct trunks from the tandem equipment to the called office (distant city, in the case of toll office tandems) are assumed; if sub-tandems are involved, a small amount of additional time is required. Also a slight additional time is involved, in the case of step-by-step tandems, if repeaters must be dialed in.

Use of Tandem Systems in Toll Board Operation

While tandem systems have been developed primarily for local and short-haul toll station-to-station traffic handled on manual or dial "A" boards, arrangements have been provided in a number of cities which give toll board operators access to existing tandem systems in

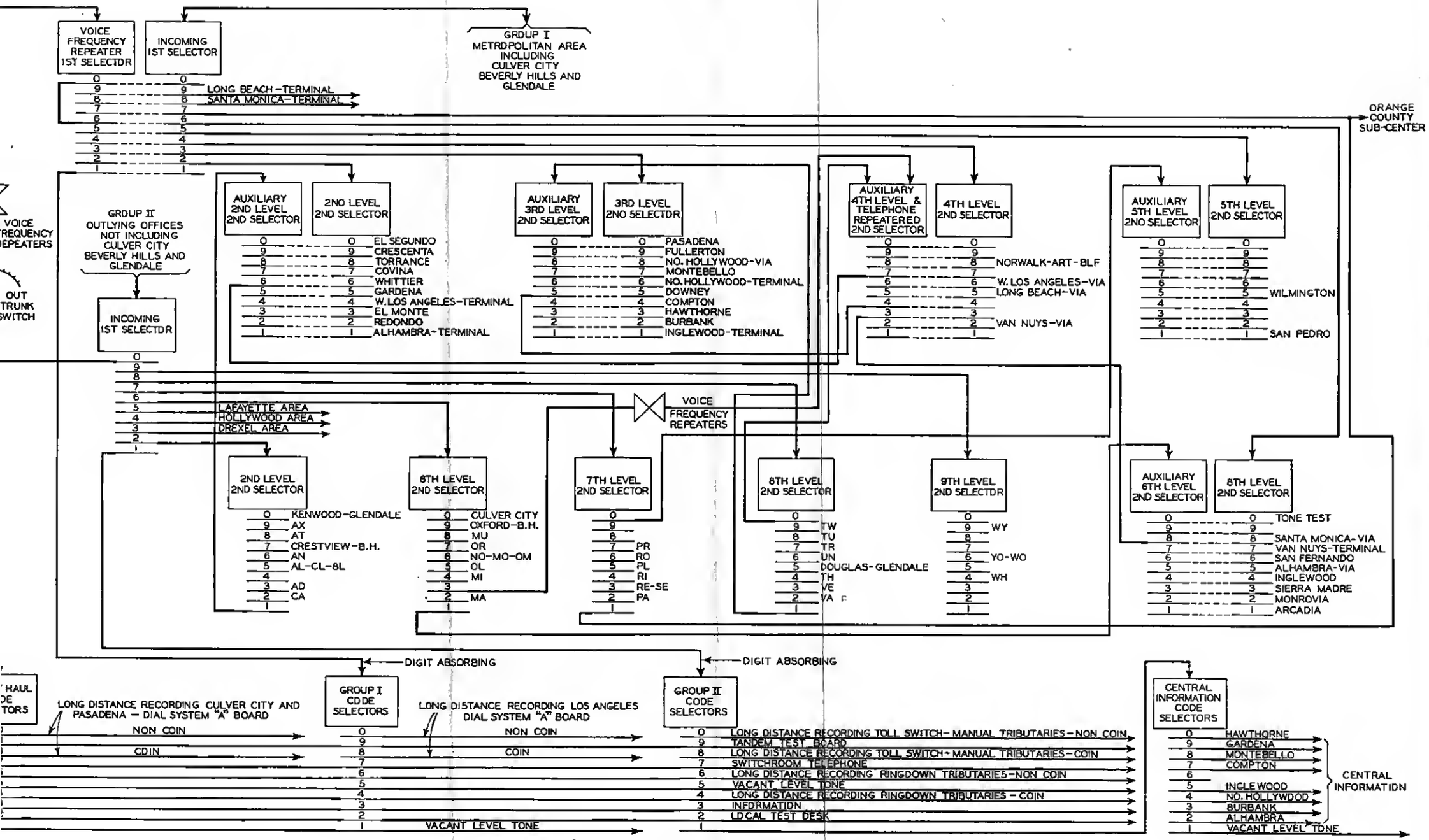

Fig. 14—Los Angeles long-haul dial tandem system.

TABLE II

RELATIVE THEORETICAL SPEED OF OPERATION OF TANDEM SYSTEMS

Type of Tandem	Types of Trunks		Speed in Seconds	
	To Tandem	From Tandem	Calls Handled By Operators*	Calls Dialed Direct By Customers†
MANUAL STRAIGHTFORWARD	Straightforward	Straightforward—to Manual "B" Pos.	25	
CALL INDICATOR	Call Indicator	Straightforward—to Manual "B" Pos.		31
TOLL OFFICE TANDEM	Straightforward	Ringdown ‡	29	
PANEL SENDER TANDEM				
Operator Tandem	Straightforward	Dial	26	
	Straightforward	Call Indicator	33	
	Straightforward	Call Announcer	34	
Full Selector Tandem From Operators at Boards Equipped with 10-button Keysets	Dial	Dial	24	
	Dial	Call Indicator	31	
	Dial	Call Announcer	32	
Dialed by Customers	Dial	Dial		28
	Dial	Call Indicator		35
STEP-BY-STEP				
Operator Tandem, with Step-by-Step "B" Board	Straightforward	Dial	22	
	Straightforward	Call Indicator	30	
Full Selector Tandem From Operators at Boards Equipped with Dials	Dial	Dial	16	
	Dial	Straightforward—to Manual "B" Pos.	20	
	Dial	Call Indicator	23	
From Operators at Boards Equipped with Keysets	Dial	Dial	17	
	Dial	Straightforward—to Manual "B" Pos.	21	
	Dial	Call Indicator	24	

* On calls handled by operators, this is the interval from receipt of signal at the switchboard to the first ring on the called line. The interval from receiver off hook at the calling station to receipt of signal, is approximately .5 second for manual stations, 3 seconds for step-by-step dial stations, and 7 seconds for panel dial stations. Both of the latter include the dialing by the customer of the "Operator" code.

† In panel areas.

‡ When completed to local multiple in toll board at called office.

order that they may complete person-to-person and other calls to points within the tandem area over tandem trunks rather than over the regular long distance circuits. Tandem systems in general make use of common battery trunks and, since some of the older types of toll switchboards either are not arranged to complete originating calls over such trunks or are not equipped with the dialing arrangements required for dialing through dial tandems, the application of this desirable arrangement is somewhat limited.

As indicated above, the only tandem operation involving ringdown toll board circuits, at present, is for the purpose of making such circuits accessible to operators at switchboard positions not having a multiple appearance of the circuits. It is the belief of the author that, with the further expansion of the long distance plant, the ringdown circuits gradually will be replaced by through supervision circuits—that is, by circuits which, like the trunks used in local and short-haul toll tandem operation, will give the originating operator switchhook supervision from the called station. These new circuits, no doubt, will be arranged for two-way and built-up circuit operation and, incoming to dial areas from toll boards equipped with dials or key sets, will be terminated directly on selectors.

Although changing conditions may suggest better arrangements, it seems probable that, from toll boards not equipped with dials or key sets, the new circuits will be operated on a straightforward basis and terminated on, or controlled at, operators' positions at the incoming end. In the larger cities these positions may have equipment and operating features quite similar to those in the panel sender tandem. In such cities, it may well be that both straightforward and ringdown incoming circuits will be terminated on switches but that the calls will be received, and both terminal and through connections set up, at the operators' positions, thus making use of the tandem type of equipment for all switching purposes in the larger cities. Also, this new inward and through toll office equipment may replace the present type of toll office tandem equipment. In smaller cities, including cities serving manual areas, the incoming circuits may be terminated on equipment having features generally similar to those in the manual straightforward system.

The gradual extension of these arrangements would eventually duplicate, in the long distance toll plant, tandem switching of the type now so extensively used on the local and short-haul toll traffic, and ultimately make the entire United States a super-tandem area.

The scope of the present tandem systems has been determined largely by economic considerations, although the desire to simplify

the service to the customer in the large metropolitan areas also has been an important factor. The general introduction of the tandem type of operation on toll board circuits may affect the economic balance, and except where other factors are controlling, will tend to limit the scope of segregated tandem systems of the present type. It may well be that, eventually, in some of the smaller cities the need for a separate tandem system for the local and short-haul toll traffic will disappear altogether.

Summary

Tandem systems for local and short-haul toll traffic have been provided:

1. To reduce the number of trunk groups required in large metropolitan areas and to insure maximum efficiency on those provided; due consideration being given, of course, to a proper balance between service and costs.
2. To permit the same operating and service arrangements on short-haul toll traffic as on local traffic, thus facilitating the work of the operators and making the service faster, and easier to use by the customer.
3. To reduce the cost of handling large volumes of short-haul toll traffic through the use of toll plant designed to meet the less exacting transmission requirements, as compared with toll plant used for long distance traffic.

These systems vary in type, depending upon the types of local central office equipment which are to be interconnected.

The use of tandem operation in connection with toll board traffic is limited at the present time, but in view of the future volume of this traffic and of new arrangements which now appear feasible, further expansion of the long distance system may be along lines generally similar to those employed in the local and short-haul toll tandem systems; using, of course, operating methods and equipment arrangements which adequately meet the requirements on the longer-haul traffic. These new arrangements may involve both dialing and straightforward toll lines. They may affect the economic balance and, thereby, the scope of tandem systems provided heretofore for local and short-haul toll traffic.

References

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